Chapter 2 section on "Normative river" Exerpted from

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Return to the River:
Restoration of Salmonid Fishes
in the Columbia River Ecosystem

Development of an Alternative Conceptual Foundation
and
Review and Synthesis of Science
underlying the Fish and Wildlife Program
of the Northwest Power Planning Council

by
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CHAPTER 2. A CONCEPTUAL FOUNDATION FOR RESTORATION OF COLUMBIA RIVER SALMONIDS

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*……………***The Normative Ecosystem**

We believe an ecosystem with a mix of natural and cultural features that typifies modern society can still sustain all life stages of a diverse suite of salmonid populations. We call this ecosystem "normative". Normative is the functional norm which ensures that we provide the essential ecological conditions and processes necessary to maintain diverse and productive salmonid populations. We emphasize that our description of the normative ecosystem is necessarily general and focuses on biological and physical processes and conditions characterizing the normative ecosystem. The normative ecosystem is not a static target or a single unique state of the river. It is a continuum of conditions from slightly better than the current state of the river at one end of the continuum to nearly pristine at the other end. The region through its policy representatives will have to decide based on its economic, cultural, and ecological values how far it will move the river along the normative continuum (Figure 2.4). Specific prescriptions, such as flow regimes, levels of stock and life history diversity, etc., will need to be developed to meet the normative ecosystem concept. We recognize that, because we are dealing with an ecosystem that has sustained extensive human development for over 150 years, numerous social and biophysical constraints exist for enhancing normative conditions. The challenge before the region is to reach consensus on the extent to which these constraints can be relaxed or removed to achieve Fish and Wildlife Program goals. Nevertheless, we believe strongly that approaching more normative ecosystem conditions is the only way in which Fish and Wildlife Program goals for recovery of salmonids and other fishes can be met. Progress toward the restoration goal would require moving the system from the current, degraded state toward normative conditions with regard to the most critical attributes for salmonids

The River Continuum

2. Sustained salmonid productivity requires a network of complex and interconnected habitats, which are created, altered and maintained by natural physical processes in freshwater, the estuary and the ocean. These diverse and high-quality habitats, which have been extensively degraded by human activities, are crucial for salmonid spawning, rearing, migration, maintenance of food webs and predator avoidance. Ocean conditions, which are

variable, are important in determining the overall patterns of productivity of salmon populations.

The Columbia River, like all large gravel bed rivers is a complex, dynamic gradient of habitat types from the headwaters to the estuary. Salmonids and all other riverine flora and fauna are distributed rather predictably along that gradient according to the requirements of each stage in their life cycle (Vannote et al., 1980). Each species or unique life history type will be present wherever there are enough resources to sustain growth and reproduction and thereby sustain the presence of the population in the river food web at that location (Hall et al., 1992). Some species can be maintained without much movement and suites of organisms appear to occur in zones along the river continuum. Other species must move long distances in search of resources needed for each life stage, sometimes involving migrations into lakes (e.g., adfluvial bull trout and cutthroat trout), the ocean (e.g., chinook salmon, coho salmon, chum salmon, and steelhead trout) or both (e.g., sockeye salmon).

Like all river ecosystems, the Columbia River has three important spatial dimensions (Figure 2.5) (Ward, 1989): 1) Riverine - a longitudinal continuum of runs, riffles and pools of varying geometry from headwaters to mouth; 2) Riparian - a lateral array of habitats from the middle of the main channel through various side and flood channels and wetlands to flood plains and the uplands of the valley wall, including streamside vegetation and associated faunal assemblages; and 3) Hyporheic - a latticework of underground (hypogean) habitats associated with the flow of river water through the alluvium (bed sediments) of the channel and flood plains. These three interconnected habitat dimensions are constantly being reconfigured by physical (e.g., flooding) and biological processes (e.g., salmon digging redds; beavers damming small streams and side channels on flood plains of larger rivers). Critical habitats for the various life stages of salmonids exist in all three dimensions.

Channel morphologies are determined by bedrock geometry and geology and by the legacy of flooding which mediates the process of cut and fill alluviation. Big floods fill channels with inorganic and organic materials eroded laterally and vertically from areas upstream, thereby producing a continuum of instream structures (pools, runs, riffles, gravel bars, avulsion channels, islands, debris jams) and lateral floodplain terraces in many sizes and shapes. Much of the Columbia River and its tributaries within the Columbia Plateau are constrained by ancient basalts (lava rock) and flood plains are not expansive. In other areas of the basin, rivers have deeply bedded and expansive flood plains interspersed between canyon reaches. Channels with a greater sediment supply and frequent overbank flooding are constantly shifting, braiding or meandering on the valley bottom from year to year as the channel fills with material in one place causing the flow pathway to erode new channels into the flood plain.

Flow of river water through interstitial pathways in gravel bars and floodplain alluvium and back to the surface is an especially important habitat forming process that may be overlooked with respect to salmonid ecology (Gibert et al., 1994). Salmonids select upwelling (water flowing upward through the gravel toward the gravel surface) and sometimes downwelling sites for spawning because their eggs are naturally aerated in those places. Nutrients increase along interstitial flow pathways and stimulate production of food for larvae and juvenile salmon in upwelling zones. The river temperatures are moderated by interstitial flow. Relative to surface temperatures, ground water from the hyporheic zone is cool in the summer and warm in the winter. Regional patterns of hyporheic flow appear to be critical to rivers of the high desert of the Columbia Plateau (e.g., Grande Ronde, John Day, Yakima), where late summer instream temperatures may be too high for salmonids (Li et al., 1995; Li et al., 1995). The upwelling zones provide cool refugia for salmonids on hot summer days and enhances winter growth by keeping the water warm and some habitats ice free. Upwelling ground water also mediates establishment of riparian plants. Leaves and wood debris eroded from the riparian zone into the channel energize the riverine food web, provide cover for fishes, and cause localized cut and fill alluviation that provides additional habitat complexity.

The importance of a complex and dynamic continuum of habitats in the Columbia River is a central tenet of our conceptual foundation. We believe that the floodplain reaches and gravel-cobble bedded mainstem segments (e.g., Hanford Reach) are especially important because habitat diversity and complexity is greatest in those locations. Alluvial reaches are arrayed along the stream continuum between canyon segments like beads on a string and appear to function as centers of biophysical organization within the river continuum (Regier et al., 1989). They are likely to be nodes of production and biological diversity that are structurally and functionally linked by the river corridor (Copp, 1989; Gregory et al., 1991; Zwick, 1992; Stanford and Ward, 1993; Ward and Stanford, 1995; Ward and Stanford, 1995). Worldwide, intermountain and piedmont valley floodplains like the Hanford Reach of the Columbia River are characterized by nutrient rich floodplain soils and diverse and productive backwater and mainstem fisheries (Welcomme, 1979; Davies and Walker, 1986; Lowe-McConnell, 1987; Sparks et al., 1990; Junk and Piedade, 1994; Welcomme, 1995). Not surprisingly, these areas are frequently centers of human activities within the watershed (Amoros et al., 1987; Petts et al., 1989; Wissmar et al., 1994).

The River Discontinuum: the Ecology of the Regulated River

At least three fundamental principles emerge from the large literature on the ecology of regulated rivers (Stanford et al. *in press*). These principles are particularly germane to derivation of restoration strategies for Columbia River salmonids.

1. Habitat diversity is substantially reduced as a consequence of regulation

The dams of the Columbia River have inundated many of the piedmont and mountain valley floodplains, thereby severing the river continuum. Mass transport dynamics that create instream and floodplain habitats for riverine biota in remaining free flowing reaches have been drastically altered. Flood peaks have been eliminated, daily discharges are more variable, and temperature seasonality has been altered.

As a consequence of reservoir storage of peak flows for flood control, navigation, irrigation, and hydropower production, base flows have increased substantially and in many places fluctuate so erratically that aquatic biota cannot survive in shallow, near-shore habitats. Persistent shallow or slack water habitats are especially important for survival of early life history stages of fishes that cannot survive in the strong currents of the channel thalweg. Storage of bedload in the reservoir and constant clear-water flushing downstream artificially has depleted gravel and finer sediments in the tailwaters causing armoring of the bed with large cobble and boulder substratum. Channel constrictions and habitat simplification is nearly universal, except in headwater areas. Vegetation has clogged backwaters owing to loss of scouring flood flow. Riparian communities have been altered by deforestation and agricultural activities which interact with effects of regulation to reduce habitat heterogeneity (all of these impacts are reviewed in detail in Chapter 5 of this report).

The general conclusion is that regulation has created a discontinuum of environmental conditions and severed the connectivity of channel, groundwater, floodplain, and upland components of the catchment ecosystem. Habitats for riverine biota have become spatially homogeneous, limited to the permanently wetted portion of the channel thalweg that is dominated by conditions dictated by operations of upstream storage reservoirs. Indeed, serial construction of low-head dams has converted virtually the entire mainstems of the lower Snake and Columbia Rivers into shallow reservoir habitat that is neither truly laucustrine nor riverine.

2. Native biodiversity decreases and non-native species proliferate as a consequence of regulation

Native biodiversity has decreased substantially in the last 120 years (Behnke, 1992; Huntington et al., 1996). Most salmon populations spawning in the mainstem Columbia and

Snake Rivers have been extirpated. In the headwaters of tributaries, salmon populations have become increasingly isolated by flow regulation, diversion and habitat degradation especially in the lower reaches. Moreover for anadromous species, mortality resulting from passage through dams and reservoirs in the mainstem may not affect all species and life histories equally, selecting against certain life history types, thereby reducing biodiversity, increasing habitat fragmentation, and increasing the vulnerability of populations to extinction.

Altered temperature patterns and continual export of very fine organic matter and dissolved nutrients, coupled with simplification of the channel, stabilization of bottom substratum, and loss of floodplain inundation, has promoted environmental conditions to which native species are maladapted (see Table 5.1 in Chapter 5 listing native and exotic fish species in the Columbia River Basin). This has created opportunities for nonnative plants and animals to establish robust populations. In some cases, one or a few native species are more abundant than they were before regulation (Poe et al., 1991). Non-native invertebrates, fishes, and plants are consistently more abundant in regulated river reaches compared to unregulated reaches (Li et al., 1987). Reasons for non-native proliferation vary, but in general non-native species are often better competitors in the homogeneous habitats of regulated river reaches. A wide array of non-natives have been introduced into the Columbia River system.

<u>3. Normative conditions are re-expressed predictably in relation to influences of tributaries and as distance downstream from the dam increases</u>

The Serial Discontinuity Concept (SDC) (Ward and Stanford, 1983; Ward and Stanford, 1995) predicts that the conditions described above that are attributable to flow regulation will ameliorate in river reaches downstream of storage reservoirs, as a natural consequence of the biophysical energetics of rivers. The distance downstream of the dam needed to reset normative conditions is related to the limnological attributes (depth, volume, water retention time, trophic state) of the reservoir, the mechanics of water release (surface, bottom or depth-selective), the mode of dam operations, and the influence of tributaries entering downstream from the dam. If the tributaries are large and unregulated, they may substantially accelerate the reset (Stanford and Hauer, 1992). In any case given enough distance, conditions at some point downstream from the dam will closely approximate original conditions.

Reset towards natural conditions has been demonstrated in Columbia River tributaries downstream of storage reservoirs, e.g., Flathead River (Hauer and Stanford, 1982; Stanford et al., 1988); Kootenai River (Perry, 1986); and Clearwater River (Munn and Brusven, 1991). For the lower Snake and Columbia Rivers, however, little reset of riverine conditions can be expected, because almost no river environments remains due to nearly continuous impoundment. The free flowing Hanford Reach is the single exception in the mainstem…………